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Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems

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Guideline Series

Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems

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2.2 DRY CLEANING PROCESSES AND EMISSIONS

2.2.1 The Basic Process

Dry cleaning is the cleaning of fabrics in an essentially non-aqueous solvent. The principal steps in the process are identical to those of ordinary laundering in water: (1) one or more washes (baths) in solvent; (2) extraction of excess solvent by spinning; and (3) drying by tumbling in an air stream. The solvents used are categorized into two broad groups: (1) petroleum solvents which are mixtures of paraffins and aromatic hydrocarbons similar--but not identical--to kerosene, and (2) synthetic solvents which are halogenated hydrocarbons--perchloroethylene and trichlorotrifluoroethane. Differences between the dry cleaning procedures for these two groups of solvents are due primarily to three factors:

- Synthetic solvents are much more expensive than petroleum solvents.
- Petroleum solvents are combustible, while synthetic solvents are nonflammable.
- The densities of synthetic solvents are about twice that of petroleum solvents.

This document discusses one synthetic solvent, perchloroethylene, only, as it is by far the most prevalent solvent type. The other synthetic solvent, trichlorotrifluoroethane, is not considered to be a photochemically reactive VOC. Petroleum solvent systems as discussed in Chapter 1 are being examined in a separate EPA study at present. By way of illustration, Figure 2-1 is a schematic of a perchloroethylene plant.

2.2.2 Perchloroethylene Systems and Emissions

Perchloroethylene machines find their major use in commercial dry cleaning plants (about 74 percent of systems). The typical neighborhood dry cleaner uses

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This report provides the necessary guidance for development of regulations limiting emissions of Volatile Organic Compounds (VOC) from perchloroethylene dry cleaning systems. Reasonably Available Control Technology (RACT) is defined and a cost analysis of RACT is included in order that cost effectiveness may be evaluated for these systems.

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Emission Standards and Engineering Division

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Office of Air, Noise, and Radiation
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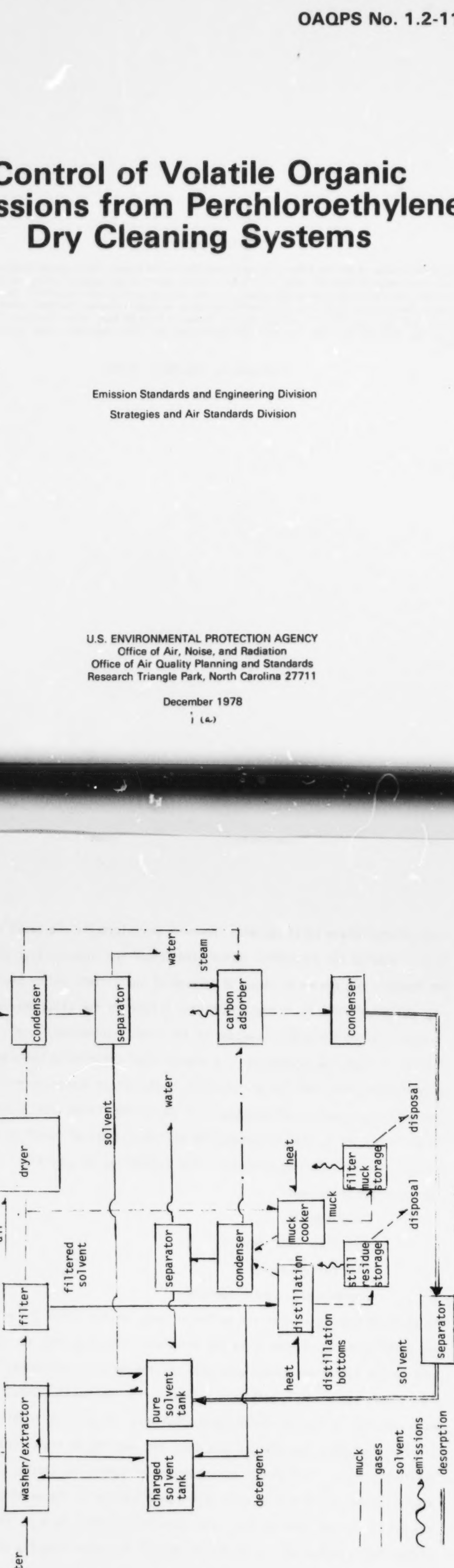
Figure 2-1. Perchloroethylene Dry Cleaning Plant Flow Diagram



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1.0 INTRODUCTION

This document is related to the control of volatile organic compounds (VOC), specifically perchloroethylene (perc), from all dry cleaning systems which use this solvent. Other solvents used in the dry cleaning industry, petroleum distillate (Stoddard Solvent) and trichlorotrifluoroethane (fluorocarbon), may be discussed in later documents.

Methodology described in this document represents the presumptive norm or reasonably available control technology (RACT) that can be applied to existing perchloroethylene dry cleaning systems. RACT is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. It may require technology that has been applied to similar, but not necessarily identical, source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source. This does not, however, preclude requiring a short term evaluation program to permit the application of a given technology to a particular source. The latter effort is an appropriate technology forcing aspect of RACT.

1.1 NEED TO REGULATE

Control techniques guidelines concerning RACT are being prepared for those industries that emit significant quantities of air pollutants in areas of the country where National Ambient Air Quality Standards (NAAQS) are not

being attained. Perchloroethylene dry cleaning systems are a significant source of VOC and are predominantly found in urban areas.

Annual nationwide emissions from perchloroethylene dry cleaning systems are estimated to be 158,000 metric tons per year or about 0.9 percent of total stationary source emissions.

The other two solvents used in the industry are not as significant as perchloroethylene. Petroleum solvent systems emit 68,000 metric tons per year and trichlorotrifluoroethane (not considered a photochemically reactive VOC) emissions are estimated to be only 820 metric tons.

1.2 SOURCES AND CONTROL OF VOLATILE ORGANIC COMPOUNDS FROM PERCHLOROETHYLENE DRY CLEANING SYSTEMS

Dry cleaning systems have several sources of emissions. The major source is the dryer (known as the recovery tumbler or reclaimer). While every perchloroethylene dryer is equipped with a condenser, significant quantities (about 50 percent) of emissions occur from this source. The disposal of waste materials is the second most significant source followed by the losses from liquid and vapor leaks.

Control techniques are available and have been widely applied in this industry. It is estimated that about 35 percent of all commercial and industrial perchloroethylene system dryers are equipped with carbon adsorbers. Emissions from waste material disposal can be reduced by several methods, among them the proper operation of cookers and cartridge filters. Finally, leaks can be prevented by visual inspection and by periodic monitoring with a leak detection instrument.

Capital costs of carbon adsorbers are $4500 for a large commercial plant of 46,000 kg (100,000 pounds) of clothes throughput per year. Cost

effectiveness of controls in this perchloroethylene system is $90 savings per metric ton of perchloroethylene removed.

1.3 REGULATORY APPROACH

The application of RACT will reduce dryer outlet concentration to less than 100 ppm; reduce emissions from filter waste and still bottoms; and eliminate liquid and vapor leaks. A study is underway to determine the significance of vapor leaks. A test procedure to define a "leak tight system" is being developed and will be available in the near future if vapor leaks are shown to be a problem.

The following sample regulation, discussed in Chapter 6.0, incorporates all of the above recommendations:

Sec. 1. Solvent emissions from perchloroethylene dry cleaning systems must be limited in accordance with the provisions of this Rule.

Sec. 2. Compliance with this Rule requires the following:

(a) There shall be no liquid leakage of organic solvent from the system.

(b) Gaseous leakage shall not exceed ____ppm. 1/

(c) The entire dryer exhaust must be vented through a carbon adsorber or equally effective control device.

1/ The EPA is currently assessing the significance of vapor leaks. If deemed significant, a test method for detecting leaks will be developed and issued to interested parties.

(d) The maximum organic solvent concentration in the vent from the dryer control device shall not exceed 100 ppm before dilution.[2/]

(e) Filter and distillation wastes.

(1) The residue from any diatomaceous earth filter shall be cooked or treated so that wastes shall not contain more than 25 kg of solvent per 100 kg of wet waste material.

(2) The residue from a solvent still shall not contain more than 60 kg of solvent per 100 kg of wet waste material.

(3) Filtration cartridges must be drained in the filter housing for at least 24 hours before being discarded. The drained cartridges should be dried in the dryer tumbler if at all possible.

(4) Any other filtration or distillation system can be used if equivalency to these guidelines is demonstrated. For purposes of equivalency demonstration any system reducing waste losses below 1 kg solvent per 100 kg clothes cleaned will be considered equivalent.

Sec. 3. Sections 2(c) and (d) are not applicable to plants where an an adsorber cannot be accommodated because of inadequate space or to plants where no or insufficient steam capacity is available to desorb adsorbers. The District may exclude other plants from the scope of Sections 2(c) and (d) if it is demonstrated that other hardships justify such an exclusion.

2/ Enforcement of these provisions is dependent on the development of a satisfactory detection instrument and test method.

Sec. 4. Compliance Procedures

(a) Liquid leakage shall be determined by visual inspection of the following sources:

(1) Hose connections, unions, couplings and valves;

(2) Machine door gasket and seating;

(3) Filter head gasket and seating;

(4) Pumps;

(5) Base tanks and storage containers;

(6) Water separators;

(7) Filter sludge recovery;

(8) Distillation unit;

(9) Divertor valves;

(10) Saturated lint from lint basket; and

(11) Cartridge filters.

(b) Vapor leakage shall be determined by _____.[3/]

(c) Dryer exhaust concentration shall be determined by _____.[4/]

(d) The amount of solvent in earth filter (2.e.1) and distillation wastes (2.e.2) shall be determined by utilizing the test method described by the American National Standards Institute in the paper, "Standard Method of Test for Dilution of Gasoline-Engine Crankcase Oils."

3/ See footnote 1, above.

4/ See footnote 2, above.

2.0 SOURCES AND TYPES OF EMISSIONS

2.1 INDUSTRY DESCRIPTION

Dry cleaning is a service industry, involved in the cleaning of apparel or renting of apparel. Basically, the industry is segregated into three areas based on customers and types of services offered. These services are: (1) coin-operated, (2) commercial, and (3) industrial.

Coin-operated dry cleaning facilities are usually part of a "laundromat" facility (although there are separate installations), and are operated on either an independent or a franchise basis. They provide a low cost "self-service" type of dry cleaning without pressing, spotting, or other services. Processing is generally about 7200 kilograms (16,000 pounds) of clothes per year per store (two systems per store). Commercial dry cleaning plants are the most familiar type of facilities, offering the normal services of cleaning soiled apparel and other fine goods. They include: small neighborhood dry cleaning shops operating on an independent basis ("Mom and Pop" dry cleaners), franchised shops (e.g., "One Hour Martinizing") and specialty cleaners, handling leather and other fine goods. Neighborhood dry cleaners generally process about 23,000 kilograms (60,000 pounds) of clothes per year. The industrial cleaners are the largest dry cleaning plants predominantly supplying rental services of uniforms or other items to business, industrial, or institutional consumers. A typical industrial cleaner processes 240,000 to 700,000 kilograms (600,000 to 1,500,000 pounds) of clothes per year. They are generally associated with large water laundry services. Nationwide perc emissions are 21,400 metric tons for coin-op, 123,000 metric tons for commercial and 13,600 metric tons for industrial dry cleaners.

a perchloroethylene based process. However, perchloroethylene-based equipment is also used in the industrial sector (EPA tested one in their test program - See Appendix A), making up about 50 percent of the systems and is used in the coin-op sector where it is the predominant solvent by far (fluorocarbon machines account for about 3 percent of the market; petroleum, none).

2.2.2.1 Solvent Characteristics - Although other chlorinated hydrocarbon solvents have been used for dry cleaning in the United States, perchloroethylene is the only chlorinated solvent seeing significant use at this time. An estimated 160 million kilograms (346 million pounds) of "perc" is used annually for dry cleaning purposes.[1] The solvent may be generally characterized as follows:

- Non-flammable,
- Very high vapor density,
- High cost ($.49/kg)
- Aggressive solvent properties.

In spite of the higher cost per gallon of perc, solvent costs for perc plants are quite competitive with those for petroleum solvent plants, its chief competitor, because the former are always used with solvent recovery equipment. Stricter fire codes, increases in petroleum solvent costs, and environmental considerations have resulted in the use of perc-based equipment for many new plants.

2.2.2.2 Equipment Characteristics - Perc machines may be either transfer or dry-to-dry types. This refers to the method of drying the clothes. In a dry-to-dry system, the drying is done in the same tumbler as the washing. Clothes are put in dry and come out dry. For transfer systems, the dryer is separate and clothes are transferred from washer to dryer. The great majority of perc machines are transfer units.

A typical commercial perc plant has a 14-27 kg (30-60 lb) capacity washer-extractor with a reclaiming tumbler of equivalent size. According to one survey about half the plants have carbon adsorption units to reduce solvent consumption.[2] A more complete survey puts this figure at 35 percent.[3] Apparently many large perc plants in the industrial sector use adsorption whereas the majority of commercial plants do not. These control devices are discussed in Chapter 3.0, Emission Control Technology.

2.2.2.3 Emission Characteristics (see Table 2-1 for summary of emissions) - As stated above, perc plants frequently have vapor adsorbers to reduce solvent usage. Typical solvent losses for both controlled and uncontrolled perchloroethylene dry cleaning plants are shown in Table 2-1 as reported by IFI.[4] These are for well-operated plants. Table 2-1 also gives average emissions from three EPA tests discussed in Appendix A.[5,6,7]

Table 2-1 shows that the uncontrolled plant can have high emission rates from filter muck and the dryer exhaust. The figure for evaporation at the dryer assumes that a condenser is used to recover a certain portion of the stream. Actually, after wash and extraction, dry cleaned materials contain about 20-25 kilograms of solvent per 100 kilograms of clothes. All of this solvent is vented to the condenser. A well-operated condenser reduces this level to 3-6 kg per 100 kg.

Other sources include evaporation at the washer (from transfer operations generally), distillation and filter waste disposal, and miscellaneous emission sources. These miscellaneous emission sources include: losses from pumps, valves, flanges, and seals; evaporative leak losses from storage vessels; chemical and water separators; and minor inefficiencies in handling solvent and material.

Table 2-1. SOLVENT LOSSES FROM WELL OPERATED PERCHLOROETHYLENE PLANTS [8,9,10,11]
(kilograms of solvent per 100 kilograms of clothing)

Source	IFI data (EPA data)[b] Plants without vapor adsorber	IFI data (EPA data)[b] Plants with vapor adsorber
Evaporation @ washer	0.54 (1)	0
Evaporation @ dryer	3 (6)	0
Vapor adsorber exhaust (properly operated)	-	0.3 (0.3)
Retention in filter muck		
· Rigid tube filter-no cooker	14	14
· Rigid tube filter-muck cooker	1.6	1.6
· Regenerative filter-muck cooker	1 (1)	1 (1)
Retention in paper cartridges		
· Drained	1.8 (0.6)	1.8 (0.6)
· Dried in cabinet vented to adsorber	-	1.2
Retention in still residue	1.6 (no data)	1.6
Miscellaneous losses (leaks)	2 (1)	2 (1)
Average Total Loss	8-21[c]	6-18[c] (3-5)

a Figures represent well-operated systems. Average emission rates by industry survey estimated at 12 kg/100 kg.

b EPA data in parenthesis.

c These ranges are high because plants could not operate economically without a muck cooker if filter is used.

According to IFI data, the usual plant has a regenerative filter with a muck cooker, and this results in a total consumption rate of about 8 kg of solvent per 100 kg of clothing. (According to one vendor, more and more plants are using cartridge filters; now in about 55 percent of commercial plants.)[12] For an adsorber-equipped plant, the corresponding solvent usage is less than 5 kg per 100 kg of clothing, which is equivalent to a 40 percent loss reduction. It should be emphasized that these usage levels are for well-operated commercial and industrial plants; average losses--including controlled and uncontrolled plants--are estimated to be about 10-12 kg of solvent per 100 kg of clothes cleaned [13] and 20 kg per 100 kg for coin-op.[14] Coin-op stores generally have higher emission rates because of underloading of equipment, lack of carbon adsorption technology, and unattended systems.

2.3 REFERENCES

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5. Kleeberg, Charles F., "Material Balance of a Perchloroethylene Dry Cleaner Unit," test report to James F. Durham, on test in Hershey, Pennsylvania, March 17, 1976.

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8. Ibid, Reference 4.

9. Ibid, Reference 5.

10. Ibid, Reference 6.

11. Ibid, Reference 7.

12. Cunniff, Joseph L., Vice President of Puritan Division, letter to Robert T. Walsh, EPA, November 21, 1978.

13. Ibid, Reference 2.

14. Anonymous Dow Chemical Survey submitted by Joseph Cunniff, Puritan Filters, to EPA on March 3, 1977.

3.0 EMISSION CONTROL TECHNOLOGY

The purpose of this chapter is to discuss control techniques for both existing and new perchloroethylene dry cleaning plants and to define emission levels that can be achieved with available control technology. Chapter 4.0 is an assessment of the costs of applying the technology.

3.1 USE OF CONTROL TECHNIQUES

For the most part, solvent emission controls for dry cleaning plants have developed out of economic necessity. In order for a more costly synthetic solvent like perchloroethylene to compete with inexpensive petroleum solvents, a substantial degree of solvent recovery is necessary during the drying operation. Solvent is recovered by condensation on all perc solvent dryers; many are equipped with adsorbers. Table 3-1 shows the extent of controls on perchloroethylene systems in the three industry sectors.

Table 3-1. POTENTIAL AND APPLIED CONTROL TECHNIQUES FOR DRY CLEANING PLANTS

	Industry Sector		
	Coin-Op	Commercial	Industrial
Carbon adsorption	N/U	35%	50% (est.)
Housekeeping	Very limited	To a degree	To a degree
Incineration	N/A	N/A	N/A
Minimize solvent loss in wastes	To a degree	To a degree	To a degree

N/A - Not applicable

N/U - None used

3.2 TYPES OF CONTROL TECHNIQUES

3.2.1 Carbon Adsorption

Activated carbon is used in many applications for the removal of organic compounds from carrier gases (usually air) by adsorption. It has been used extensively to recover perchloroethylene from dry cleaning systems. Adsorption is the property of a surface to retain molecules of a fluid which have contacted the surface. Perchloroethylene can be retained on carbon very easily. The working bed capacity (weight of solvent per weight of carbon, expressed as percent) for perchloroethylene is about 20 percent.[1]

The cost of perchloroethylene solvent has encouraged and necessitated recovery of some kind. The earliest units used water cooled or refrigerated condensers to control 85-90 percent of losses from the dryer. Rising solvent costs made adsorption of the remaining 10-15 percent attractive. Carbon adsorption has been used on perchloroethylene units for years.

EPA collected data during plant tests on three carbon adsorption units used with perchloroethylene systems. Appendix A of this report details the results of those tests. Table 3-2 summarizes the data and shows inlet and outlet concentrations associated with each of the three tests. Outlet concentrations ranged from 2 to 100 ppm as perchloroethylene. Collection efficiencies ranged from 96 percent to 99.6 percent.

Also seen in Table 3-2 is a list of the sources controlled. In each case, vapors were drawn off at the dryer and washer, at least. Generally, a current of fresh air is required for occupational safety at the operator's face when loading and unloading. This is usually accomplished by an internal fan (activated by door opening) which draws air through

Table 3-2. CARBON ADSORBER TEST SUMMARY FOR THREE PERCHLOROETHYLENE PLANTS

Plant	Process (units vented)	Clothes cleaned per day	Inlet concentration ppm	Outlet concentration ppm[3]	Outlet mass rate kg/day	Size of unit (floor space)
A	Transfer, commercial perchloroethylene [1](Washer door, dryer, floor vents, distillation unit vent)	450 kg/day	600	25	1	40 sq.ft. (3.7 sq. meters)
B	Transfer, industrial, perchloroethylene [1](Washer door, dryer)	1750 kg/day	5300-6500	2	0.1	60 sq.ft. (5.6 sq. meters)
C	Dry to dry, commercial, perchloroethylene [1](Washer/dryer door, dryer, floor vents)	170 kg/day	3300	100[2]	1.5	12 sq.ft. (1.1 sq. meters)

[1] Indicates the emission sources that were vented to the carbon adsorber.

[2] Limited semicontinuous data show this adsorber to have been underdesigned.

[3] For one cycle of adsorption-desorption of a single bed.

a duct at the machine door lip. The air, laden with solvent vapor, is then passed to the carbon adsorber.

Dryers usually vent during specific points in the drying process. The dryer exhaust is generally chilled to remove solvent and then reheated and recirculated to the dryer. At the end of the drying cycle, the clothes are hot and must be cooled gradually to avoid wrinkles. Fresh air is drawn in (in a process called deodorizing) and is vented to the adsorber (since condensation would not be effective on the low concentration stream). Dryers also vent to the adsorber whenever the overheat thermostat is actuated causing cool air to enter an overheated dryer. At least one system design vents dryer exhaust to the adsorber continuously (Plant C was an example) for system simplification.

Floor vents are installed to control fugitive vapors around the machines and to draw vapors from solvent spills. These vents have been located on the floor next to the front of machines and next to filter systems. There is some evidence that these vents are more effective if they are located at the same level as the solvent emission; perchloroethylene vapors do not necessarily drop to the floor because of the solvent's density.[2]

There is no technical reason why all sources in dry cleaners vented through a stack or duct to atmosphere cannot be directed to a carbon adsorber. This includes distillation units, washer loading vents, storage tanks, and chemical separators. None of these vents has an extremely high volume of vapor to be treated. Emissions from these sources and other pertinent data are described in Appendix A.

For perchloroethylene based units, carbon adsorption can be used to achieve 100 ppm or less outlet concentration on the sources discussed above.

Space requirements vary with the size of the unit. For the three plants tested the adsorber floor space is shown in Table 3-2. These area estimates include piping, canister, and ductwork.

Coin-operated perchloroethylene systems have special problems. There is generally no steam demand at coin-ops and thus no steam boiler. In most cases, the steam necessary to desorb a carbon bed does not exist at these plants and necessary space for an adsorber is not available. Either the carbon bed must be portable and taken off-site for regeneration or a steam boiler must be added at each site. EPA examined the feasibility of regenerating carbon beds off-site and found space requirements and costs high. (The capacity of the bed must be large to accommodate solvent recovered over long periods of time or else the carbon must be regenerated often.) While coin-operated perchloroethylene dry cleaners have had only limited use of carbon adsorbers, the technology for perchloroethylene recovery is certainly demonstrated. Costs are evaluated in Chapter 4.0 and include boiler installation costs. EPA will continue to evaluate methods of controlling coin-operated systems.

3.2.2 Housekeeping

The losses associated with poor maintenance of equipment are difficult to quantify. A few devices, however, control major emission sources in dry cleaning plants; neglect of these devices can significantly contribute to high solvent loss. Other sources of emissions--fugitive or miscellaneous--are not associated with "point losses" or losses from obvious areas such as venting of dryers or disposal of filter wastes. Fugitive emission points include leaks from valves, flanges, seals, and covers on storage tanks.

There are two types of losses from both point and fugitive emission sources--liquid and vapor. Liquid losses can be detected by sight--the brown residue associated with a solvent leak is familiar to any operator. One solvent manufacturing company[3] estimates that a leak of one drip per second equates to as much as four litres of solvent per day. Because of the volatility of the solvents, these liquid leaks are eventually evaporated to atmosphere. Vapor leaks can be detected by smell, application of soap and water to sources, or hydrocarbon detectors. EPA is currently evaluating the significance of vapor leaks and also a number of methods of detecting vapor leaks and will advise at a later date on the optimum approach. Our objective is to develop an inexpensive monitor which can be used to detect major vapor leak sources. Vapor losses usually occur at evaporative points and tears in ductwork. The solvent manufacturer has submitted a list of common emission areas[4] which should be checked periodically to control these losses. The following checklist is similar to those used by other vendors[5,6,7] to advise customers on how to maintain equipment.

Liquid leakage areas include:

a) Hose connections, unions, couplings and valves.

b) Machine door gasket and seating.

c) Filter head gasket and seating.

d) Pumps.

e) Base tanks and storage containers.

f) Water separators (lost in water due to poor separation).

g) Filter sludge recovery (lost in sludge by improper recovery).

h) Distillation unit.

i) Divertor valves.

j) Saturated lint from lint basket.

k) Cartridge filters.

Vapor leakage areas include:

a) Deodorizing and aeration valves on dryers (the seals on these valves need periodic replacement).

b) Air and exhaust ductwork (solvent lost through tears in duct).

c) Doors left open are problems. Leaks in the system should be confined to the closed washer and/or dryer if possible.

d) Button traps and lint baskets should be opened only as long as necessary.

Other areas include:

a) Lint screens and bags, fan blades and condensers can adversely affect capture systems if they are clogged or caked with lint.

b) Overloading and underloading can increase losses. Overloading makes drying difficult. Underloading is self-defeating since most losses are fixed in the system.

c) Inefficient extraction due to overloading or loose belts can cause poor drying.

Rapid detection and repair of leaks is essential to minimize solvent losses. Table 3-3 shows how neglect of certain pieces of equipment can increase solvent consumption from the well-controlled plant usage of 3-5 kg per 100 kg of clothes cleaned to the neglected plant loss of greater than 15 kg per 100 kg. These data were derived from plant tests, vendors, industry data, and estimates. In one solvent company survey, plants reported solvent usages from less than 2 kg per 100 kg to above 35 kg per 100 kg. Average use was around 12 kg per 100 kg.[8] Good housekeeping practices require very little additional effort in existing plants. No new equipment is needed and little cost is incurred.

Table 3-3. EFFECT OF HOUSEKEEPING PRACTICES ON PERCHLOROETHYLENE SOLVENT LOSSES

Plant	Source	Well controlled kg/100 kg [1/]	Neglected kg/100 kg [2/]	Problem Areas
Perchloroethylene	Dryer	0-1	(see carbon adsorber)	
	Filter muck	1	up to 14	15 represents uncooked muck
	Cartridge	1-2	1-2	
	Still residue	1.6	greater than 1.6	
	Washer	0	0 (see below)	
	Carbon adsorber	0.3	3-6	Represents inlet to carbon adsorber. Poor desorption.
	Miscellaneous	1-2	2-4	Estimated loss.

1/ Based on EPA plant tests and vendor data.

2/ Based on average emission factors developed by industry surveys and testing.

3.2.3 Incineration

Incineration, while technically feasible for control of perchloroethylene is impractical for halocarbons.

Perchloroethylene is virtually inflammable and large quantities of supplemental fuel must be used to combust it. Incineration can produce hydrogen chloride (HCl), chlorine (Cl) and phosgene ($COCl_2$).[9] All of these compounds can be removed by scrubbing exhaust gases with water. However, some water treatment would likely be required.

3.2.4 Waste Solvent Treatment

Solvent is recovered from filter muck (diatomaceous earth, carbon, lint, detergents, oils, and solvent) and from distillation bottoms. In many perchloroethylene systems solvent is "cooked" out of filter materials. EPA data[10,11] show that well controlled plants can make this potentially large emission source an insignificant one by direct and indirect steam distillation.

Other options for disposal include recovery off site by a solvent disposal vendor and cartridge filtration. Cartridge filters have inherent design advantages (they are confined and contained) which give them a low emission factor (1 kg/100 kg) when properly drained and dried and are applicable to low soil loadings such as commercial operations.[12]

Solvent losses from distillation bottom disposal can be reduced in oil cookers (similar to muck cookers) to levels well below 1 kg/100 kg of clothes cleaned by proper operation of existing equipment according to a test conducted by EPA.[13] Operators should avoid premature shutdown of the distillation unit.

There would be no additional space requirements for filter units in perchloroethylene systems and, of course, no additional space would be required to improve the "cooking" of existing distillation systems.

3.3 SUMMARY

This chapter has discussed control techniques for both existing and new perchloroethylene dry cleaning plants. Carbon adsorption can be used to control perc vapor vented from the washer, dryer, storage tanks, distillation systems, and chemical separators to less than 100 ppm.

Incineration does not appear applicable to synthetic solvent plants because of associated environmental penalties.

Muck cookers are generally used in perchloroethylene plants and, if operated properly, maintain losses at less than 1 kg/100 kg of clothes cleaned. Drained and dried cartridge filters achieve less than 1 kg per 100 kg of clothes cleaned based on EPA tests and thus are another effective means of control of this source.

Miscellaneous emissions can be controlled through the use of better housekeeping--aided by portable, inexpensive monitors (to be developed by EPA).

In short, the emissions from dryers, washers, distillation units, holding tanks, filter systems, and fugitive emission sources can all be controlled by the above named systems. Table 3-4 summarizes sources, applicable control techniques, and achievable emission levels.

Table 3-4. CONTROL TECHNIQUES AND SOLVENT EMISSION LEVELS
DRY CLEANING

Type of Plant	Source	Emission Level kg/100 kg	Control Techniques	Controlled Level kg/100 kg
Perchloroethylene	Washer	2	Carbon adsorber	0.5-1.0
	Dryer	6	Carbon adsorber	
	Filter waste	1.5	Proper draining of cartridge filters or longer cooking times for filter waste.	0.5-1.0
	Still residue	1.6	Longer distillation	0.5-1.0
	Miscellaneous	1-3	Good housekeeping	1 - 3

3.4 REFERENCES

1. Barber, J.W., Research Director, Vic Manufacturing Company, Minneapolis, Minnesota, letter to C.F. Kleeberg, EPA, February 6, 1976.

2. Discussion with William Fisher, IFI, Silver Spring, Maryland, August 7, 1975.

3. Anonymous, Dow Chemical U.S.A., "Poor Solvent Mileage - Professional Dry Cleaning Plants," submitted by Bob Lundy, Dow Chemical to Charles F. Kleeberg, EPA, March 16, 1976.

4. Reference 3, Op. Cit.

5. Anonymous, Hooker Industrial Chemicals, Bulletin Number 185, "Hooker Handbook for Dry Cleaners," p.10.

6. Vic Manufacturing Company, "Installation and Operation Instruction for Vic Models 221 and 222," VMC 1195.

7. Reeves, H.E., "Causes of Excessive Loss of Perchloroethylene," IFI Practical Operating Trips Bulletin, p.91, January, 1969.

8. Anonymous, Dow Chemical USA, "Dow Customer Survey," submitted by Bob Lundy, Dow Chemical to Billy C. McCoy, TRW Services.

9. "Chlorinated Solvents: Toxicity, Handling Precautions, First-Aid," Dow Chemical, U.S.A., Form No.100-5449-74R.

10. Kleeberg, C.F., "Testing of Commercial Perchloroethylene Dry Cleaner," test report on Hershey, Pennsylvania, test, to James F. Durham, EPA, May 14, 1976.

11. Kleeberg, C.F., "Testing of Industrial Perchloroethylene Dry Cleaner," test report on San Antonio, Texas, test, to James F. Durham, EPA, May 14, 1976.

12. Kleeberg, Charles F., "Testing of Commercial Perchloroethylene Dry Cleaner," test report on Kalamazoo, Michigan, test, to James F. Durham EPA, May 17, 1976.

13. Ibid, Reference 11.

4.0 COST ANALYSIS

4.1 INTRODUCTION

4.1.1 Purpose

The purpose of this chapter is to present estimated costs for applying emission control techniques to perchloroethylene dry cleaning systems. Cost data will be supplied for hydrocarbon control at perchloroethylene solvent plants.

4.1.2 Scope

Control cost estimates will be presented for three types of facilities using perchloroethylene solvents: coin-operated plants, industrial plants, and commercial dry cleaners. These estimates will reflect the retrofit control cost of carbon adsorption for control of washer and dryer emissions. No incremental costs for housekeeping controls are presented.

4.1.3 Use of Model Plants

Control cost estimates are presented for typical model plants in the dry cleaning industry. Specific model plant parameters will be presented in subsequent portions of this chapter. It is admitted that control costs at actual installations may vary, sometimes appreciably, from the costs described for the model plants. However, the difficulty of obtaining actual plant control cost information makes the use of model plants a necessity. To the extent possible, EPA has incorporated actual plant cost information into the cost analysis.

Cost information is presented for typical existing model facilities. In some cases, model plants of varying sizes have been developed. The purpose of this is to show the relative variation in control equipment

costs with plant size. Whereas the plant sizes chosen for analysis are believed to be representative of plants in the industry, no attempt has been made to span the range of existing plant sizes.

4.1.4 Bases for Capital Cost Estimates

Control cost estimates are comprised of installed capital costs and annualized operating costs. The installed capital cost estimates reflect the cost of designing, purchasing, and installing a particular control device. These estimates include costs for both major and auxiliary equipment, removal of any existing equipment, site preparation, equipment installation, and design engineering. No attempt has been made to include costs for lost production during equipment installation or start-up. All capital costs reflect first quarter 1978 costs. In general, information on capital costs for alternative control systems has been developed through contacts with control equipment vendors. In addition, some information from EPA files has been used along with data from previous contractor studies of the dry cleaning industry.

4.1.5 Bases for Annualized Cost Estimates

Annualized cost estimates include costs for operating labor, maintenance, utilities, credits for solvent recovery, costs for waste disposal, and charges for depreciation, interest, administrative overhead, property taxes, and insurance. A return on the pollution control investment is not included in the annual cost estimate. All annualized costs reflect second quarter 1978 costs. Operating cost estimates have been developed by EPA from in-house files. Credits for solvent recovery have been calculated based on emission factors presented in Chapter 3 and the current market price of $0.49/Kg for perchloroethylene solvent.[3] It is estimated

that this solvent price could vary 20% depending on location and quantities purchased. Estimates of depreciation and interest costs have been calculated by EPA by using a capital recovery factor based on the assumptions of an interest rate of 10 percent and a depreciable equipment life of 10 years. In addition to costs for depreciation and interest, an additional charge of 4 percent of total capital has been added for administrative overhead, property taxes, and insurance.

4.2 PERCHLOROETHYLENE SOLVENT PLANT COST ANALYSIS

4.2.1 Model Plant Parameters

Control costs have been developed for three types of perchloroethylene solvent dry cleaning plants. These are coin-operated plants, commercial plants, and industrial plants. The model plant parameters that were developed for these facilities are displayed in Table 4-1. The model perchloroethylene plant parameters are based upon industry contacts and EPA studies of the industry. Typical plant sizes for perchloroethylene solvent plants are two 3.6 Kg unit in a coin-op store, one 11 Kg unit in a commercial plant and one 93 Kg unit in an industrial plant.

4.2.2 Control Costs - Perchloroethylene Plants

Costs for control of washer and dryer emissions from coin-operated, commercial, and industrial perchloroethylene solvent plants have been calculated.

Table 4-2 presents costs for carbon adsorber controls for five sizes of model new and existing perchloroethylene plants - 3.6 Kg/load, 11 Kg/load, 23 Kg/load, 91 Kg/load, and 114 Kg/load. Costs are presented in terms of installed capital costs, annualized costs, and the cost per kilogram of

Table 4-1. COST PARAMETERS FOR MODEL PERCHLOROETHYLENE PLANTS[a]

	Coin-Op	Commercial Plant		Industrial Plant	
Washer load capacity (Kg)	2 units @ 3.6 Kg ea.	11	23	91	114
Annual washer loads	525	2,210	2,113	4,484	5,007
Dryer exhaust flow (ncms)	.46	.59	1.23	12.05	18.02
Dryer exhaust temperature (°C)	24	24	24	24	24
Uncontrolled washer and dryer emission (Kg/100Kg)[b]	7	7	7	7	7
Uncontrolled muck emissions (Kg/100Kg)[b]	1.5	1.5	1.5	1.5	1.5
Uncontrolled still and miscellaneous emissions[b]	3.5	3.5	3.5	3.5	3.5
Solvent cost ($/Kg)[c]	0.49	0.49	0.49	0.49	0.49

a) Source: Except as noted, EPA assumptions based on industry contacts, contractor studies, and EPA files.

b) Source: Table 3-5.

c) Source: Ref. 3

Table 4-2. COSTS FOR CARBON ADSORPTION FOR PERCHLOROETHYLENE SOLVENT PLANTS

Unit Size (Kg)	2 units @ 3.6 Kg ea.	11	23	91	114
Plant Type	Coin-op	Commercial	Commercial	Industrial	Industrial
Model Existing Facilities					
Installed capital ($000)	8.0 [a]	3.2 [b]	4.5 [b]	8.2 [b]	9.8 [b]
Direct operating cost ($000/yr) [c]	.7	.6	.3	0.8	.9
Capital charges ($000/yr) [d]	1.6	.7	.9	1.7	2.0
Solvent cost/(credit) ($000/yr) [e]	(0.1)	(0.8)	(1.5)	(12.0)	(18.2)
Net annualized cost/(credit) ($000/yr)	2.2	0.5	(0.3)	(9.8)	(15.3)
Controlled emissions (1000 Kg/yr) [e]	.3	1.6	3.2	24.8	37.2
Cost/(credit) per Kg controlled ($/Kg)	7.33	.31	(0.09)	(0.38)	(0.41)

a. Reference 1
b. Reference 2
c. Reference 4
d. Calculated @ 10% for 10 years + 4% for taxes, insurance and administrative
e. Based on emission factors given in Table 3-4.

hydrocarbon controlled for the different sizes. Note that for carbon adsorption that not only are total capital costs and total annualized costs presented but also presented is information on the cost-effectiveness of each size plant. For example, for the model 11 Kg/load commercial plant the total installed capital cost from Table 4-2 for a carbon adsorber is estimated to be $3,200, the net annualized cost is estimated to be $500/year, and the cost per kilogram of hydrocarbon controlled is estimated to be $0.31/Kg.

This estimate of $0.31/Kg is determined by dividing the net annualized cost of $500/year by the controlled emissions of 1600 Kg/year. The controlled emissions were determined from Table 3-4. Table 4-3, which shows that control option #1 for perchloroethylene solvent plants combines carbon adsorption, waste solvent disposal, and good housekeeping practices. The recovered emissions are 6.5 Kg/100 Kg (11.5 Kg-5 Kg). An 11 Kg load system doing 2210 loads per year (Ref. Table 4-1) cleans 24,300 Kg/year of clothes. Multiplying this figure by 6.5 Kg/100 Kg results in controlled emissions of approximately 1600 Kg/year.

It should be noted that emission reductions attributable to housekeeping controls have been included in some control options. As stated before, however, no costs for housekeeping controls have been included since they are believed to be adequately accounted for by the charge of four percent of total capital that is allocated to all control systems to cover administrative overhead taxes, and insurance and the 6 percent of total capital allocated to cover operating and maintenance. Also note that costs for a carbon adsorber for 3.6 Kg plants are larger than carbon adsorber costs for

Table 4-3. COST-EFFECTIVENESS OF ALTERNATIVE CONTROLS FOR EXISTING PERCHLOROETHYLENE SOLVENT PLANTS ($/Kg Controlled)

Plant Size	2 units @ 3.6 Kg ea.	11	23	91	114
Plant Type	Coin-op	Commercial	Commercial	Industrial	Industrial
Option #1: Approximately Equal to: 5 Kg/100 Kg					
Carbon adsorption, proper waste solvent disposal, good housekeeping practices	7.33	0.31	(0.09)	(0.38)	(0.41)
Option #2: Approximately Equal to: 12 Kg/100 Kg	0*	0	0	0	0

Basis: Tables 4-2 *NOTE: Coin-op owners may incur some costs due to increased maintenance of these dry cleaning systems under this option. However these costs are not quantifiable.

either an 11 Kg plant or a 23 Kg plant. This is because it was assumed that the 3.6 Kg plants would not have steam available for regeneration of the carbon but the larger plants would have such capacity. Therefore, it was necessary to include the cost of a small steam boiler in with the cost of the carbon adsorber for the 3.6 Kg plants. In the case of the larger perchloroethylene plants it was assumed that steam was available and no costs were included for purchase of a boiler.

4.2.3 Cost Effectiveness

Summary costs in terms of the cost per kilogram of solvent emissions controlled is presented in Table 4-3 for different size perchloroethylene plants. Control costs decrease rapidly as the size of the unit controlled increases. For example, carbon adsorber controls cost $7.33/Kg in a 3.6 Kg/load facility but decrease to a net credit of ($.41/Kg) for a 114 Kg/load facility.

4.3 REFERENCES FOR CHAPTER 4.0

(1) Cost data and equipment brochures furnished by Mrs. Pat King, Executive Assistant, HOYT Manufacturing Corporation, and Mr. Peter Zizzi, Sales and Service Engineer, Fulton Boiler Works, Incorporated.

(2) Information furnished by Mr. A. C. Cullins, Laundry and Dry Cleaning Consultant, Standard Laundry Machine Company, Inc.

(3) Virginia-Carolina Laundry Supply Company, 639 Junction Road, Durham, North Carolina.

(4) Operating cost based on projections of equipment brochures and specifications furnished by Vic Manufacturing Company, 1620 Central Ave. N.E., Minneapolis, Minnesota 5541.

5.0 EFFECTS OF APPLYING THE TECHNOLOGY

The air pollution impacts and the other environmental consequences of applying the control technology presented in Chapter 3.0 are discussed in this section. A comparison will be made between emissions from a typical uncontrolled plant and those from plants using alternative control techniques. Beneficial and adverse impacts which may be directly or indirectly attributed to the operation of these systems will be assessed.

Both direct and indirect impacts are involved in the control of dry cleaning plants. For example, reduced air emissions, increased water consumption, and increased energy demand are all impacts directly related to the use of carbon adsorption recovery systems. Incremental emissions from a boiler used to supply additional steam to the adsorber are an indirect impact.

5.1 IMPACTS ON VOC EMISSIONS

Pollutant emission factors for the individual uncontrolled plant are shown in Table 5-1. They are based upon data from the literature (including trade associations, [1,2] equipment vendors,[3] and solvent companies[4]) and from stack test data[5,6,7] obtained during this study.

Table 5-2 shows the individual sources of emission within the plant and the achievable level with applicable control technology for each source. The methods include carbon adsorption for washers and dryers; longer distillation times for distillation units; longer cooking times or cartridge filter substitution for filter muck; and leak prevention measures for miscellaneous losses.

Table 5-1. HYDROCARBON EMISSION FACTORS
UNCONTROLLED TYPICAL PLANTS

Type of Plant	Solvent	Plant Throughput	Uncontrolled		
			kg/100 kg of clothes cleaned	kg/yr	lb/yr
Coin-op	Perchloroethylene	7,300 kg/yr (16,000 lb/yr)	20	1,460	(3,200)
Commercial	Perchloroethylene	27,000 kg/yr (60,000 lb/yr)	12	3,240	(7,200)
Industrial	Perchloroethylene	270,000 kg/yr (600,000 lb/yr)	12	32,400	(72,000)

Table 5-2. EFFECT OF APPLYING AVAILABLE AIR POLLUTION CONTROL TECHNIQUES TO MODEL PLANTS

	Perchloroethylene System kg/100 kg of clothes	
	Uncontrolled	Controlled
Dryer	6	Carbon Adsorber 0.6
Discarded Filter Muck	2	1
Cartridge Filters	1	1
Discarded Still Residue	1.6	0.5 (Test Data)
Washer	2	0.1
Miscellaneous Sources	1-3	1-2
TOTAL	12	< 5

Note: Uncontrolled emission estimates are best expressed as ranges because of the wide differences in operation efficiencies in the industry. These estimates are based on industry data and EPA plant tests and represent approximate mid-range for most sources. Some controlled sources are estimated.

5.2 OTHER AIR POLLUTION IMPACTS

There are no other air pollution impacts associated with any of the control techniques.

5.3 WATER POLLUTION IMPACTS

Dry cleaning processes usually discharge some water to sewage facilities. Perchloroethylene plants use water cooled condensers. Some plants have water washes to remove soluble soils. Many perchloroethylene plants use steam for heating dryer air, presses and finishing equipment, and for distillation or muck cooking purposes. The air pollution control systems envisioned for dry cleaning facilities will add to the amount of water used as indicated in Table 5-3. Data are based on plant tests[8,9,10] and vendor submittals.[11] It should be noted that increased water usage is estimated only for those sources where water may come in contact with solvent. This does not include condenser water which will total about 750 liters per day for a commercial system.

The primary addition would be the steam required to regenerate the carbon. Typically about 45 kg of steam is required per 100 kg of clothes cleaned. Condensate is generally disposed of by sewer (about 55 liters per day).

Also shown in Table 5-3 is the steam (and thus water) required for a muck cooker or distillation unit. These units are generally present in perchloroethylene plants.

EPA has not promulgated or proposed effluent guidelines for dry cleaning solvent content in waste water streams. During plant tests for this project, EPA took water samples of streams from carbon adsorbers and found them to contain less than 100 ppm perchloroethylene by weight. The effluent was disposed of in sanitary sewers.

Table 5-3. IMPACT OF AIR POLLUTION CONTROL SYSTEMS ON WATER USAGE

Plant Type	Control Methods	Water Usage kg/yr	Notes
Coin-Op Perchloroethylene	Carbon adsorber	1,600	Water rate of 45 kg H_2O/100 kg clothes
	Filter drying	0	
	Housekeeping practices	0	
Commercial Perchloroethylene	Carbon adsorber	12,150	Water rate of 45 kg H_2O/100 kg clothes; steam for muck cooker 5 kg H_2O/100 kg assumed.
	Muck cooker	1,350	
	Housekeeping	0	
Industrial Perchloroethylene	Muck cooker	13,500	Water rate of 45 kg H_2O/100 kg clothes; steam for muck cooker 5 kg H_2O/100 kg assumed.
	Housekeeping	0	
	Carbon adsorber	121,500	

Table 5-4. PERCHLOROETHYLENE SOLVENT IN EFFLUENT WATER AS A RESULT OF CARBON ADSORPTION (MODEL PLANTS)

	Increased water usage (kg/year)	Solvent disposed of (kg/year)
Coin-Op	1,600	0.2
Commercial	13,500	1.4
Industrial	135,000	13.4

Assumes 100 ppm in effluent

Using the figure of 100 ppm in water for perchloroethylene plants, Table 5-5 shows that 13.5 kilograms of solvent per year will be added to effluent from typical industrial plants; less from coin-op and commercial establishments.

5.4 SOLID WASTE IMPACT

There is little solid waste impact associated with air pollution control techniques. Carbon in adsorbers eventually must be replaced because of "blinding" of the bed by small pieces of lint and other particulate. Vendors and users have estimated the life of carbon at up to 30 years. The carbon can be regenerated, but may be discarded every 15 years. Each commercial perchloroethylene plant uses around 100 kilograms of carbon. Large industrial perc plants use up to 450 kilograms. The solid waste impact from the entire industry is estimated to be insignificant--even if all plants used carbon adsorbers.

The techniques used to reduce emissions from solvent filters do not increase solid waste at all; they do reduce the amount of solvent in discarded muck and filters. The emission reduction from control of filter disposal is part of the total emission reduction shown in Table 5-2.

5.5 ENERGY IMPACT

Certain control techniques require additional energy. Carbon adsorbers require steam for desorption. Muck cookers and distillation oil cookers both require steam, but in many plants already equipped with boilers the energy increment is small.

5.5.1 Impact on Model Plant

Table 5-5 shows the energy impact of the above alternatives on model plants. There is also the possibility of an energy credit from the decreased use of solvent which would be a result of these alternatives if implemented in the plants. It is estimated that at least one kilogram of fuel would be

Table 5-5. ENERGY IMPACT OF ALTERNATIVE CONTROL LEVELS ON TYPICAL PLANT

Plant	Control	10^6 BTU/yr Usage	10^6 BTU/yr Savings	Net Energy Usage (savings) 10^6 BTU/yr
Coin-Op				
Perchloroethylene	Carbon adsorber Muck cooker	6.6	(25)	(18)
Commercial				
Perchloroethylene	Carbon adsorber	27	(45)	(18)
Industrial				
Perchloroethylene	Carbon adsorber	270	(430)	(160)

required to produce one kilogram of solvent. Table 5-5 shows this solvent savings as an energy credit for each plant. (Actually, the energy savings would be creditable to the solvent producer.) Net energy consumption is shown as a savings.

5.5.2 Impact on Indirect Air Pollution

Increases or decreases in steam demand as a result of applying the control techniques will influence emissions from the boiler plant. These emissions are considered insignificant.

5.6 REFERENCES

1. Watt, Andrew, IV, and William E. Fisher, "Results of Membership Survey of Dry Cleaning Operation," IFI Special Reporter #3-1, January-February, 1975.

2. Fisher, William E., "The ABC's of Solvent Mileage," Part One, IFI Special Reporter #3-4, July-August, 1975.

3. Barber, J.W., Research Director, Vic Manufacturing Company, Minneapolis, Minnesota, letter to C.F. Kleeberg, U.S. EPA, February 6, 1976.

4. Anonymous, "Dry Cleaning Industry Statistics," submitted by Robert Lundy of Dow Chemical from Dow Survey.

5. Kleeberg, Charles F., "Material Balance of a Perchloroethylene Dry Cleaner Unit," test report to James F. Durham on test in Hershey, Pennsylvania, March 17, 1976.

6. Kleeberg, Charles F., "Material Balance of an Industrial, Perchloroethylene Dry Cleaner," test report to James F. Durham, on test in San Antonio, Texas, May 14, 1976.

7. Kleeberg, Charles F., "Material Balance of Small Commercial Perchloroethylene Dry Cleaner," test report to James F. Durham on test in Kalamazoo, Michigan, May 17, 1976.

8. Ibid, Reference 5.

9. Ibid, Reference 6.

10. Ibid, Reference 7.

11. Vic Manufacturing Company, "Model 221 Strato Dry to Dry Series Specifications," Form Number 221-1083, June, 1971.

6.0 ENFORCEMENT ASPECTS

6.1 AFFECTED FACILITY

In formulating regulations it is suggested that the affected facility be defined as the dry cleaning system which includes: washer, dryer, filter and purification systems, waste disposal systems, holding tanks, pumps, and attendant piping and valves. This definition would cover all significant VOC sources of emissions in perchloroethylene plants.

6.2 SUGGESTED REGULATION

The ease of determining compliance is the most important consideration in development of regulations for such a prevalent source as perchloroethylene dry cleaning. The following example regulation outlines the method deemed to be optimum for reducing emissions.

Rule_____ of _____ Air Pollution Control District

Sec. 1. Solvent emissions from perchloroethylene dry cleaning systems must be limited in accordance with the provisions of this Rule.

Sec. 2. Compliance with this Rule requires the following:

(a) There shall be no liquid leakage of organic solvent from the system.

(b) Gaseous leakage shall not exceed _____ppm.[1/]

1/ The EPA is currently assessing the significance of vapor leaks. If deemed significant, a test method for detecting leaks will be developed and issued to interested parties.

(c) The entire dryer exhaust must be vented through a carbon adsorber or equally effective control device.

(d) The maximum organic solvent concentration in the vent from the dryer control device shall not exceed 100 ppm before dilution.[2/]

(e) Filter and distillation wastes.

(1) The residue from any diatomaceous earth filter shall be cooked or treated so that wastes shall not contain more than 25 kg of solvent per 100 kg of wet waste material.

(2) The residue from a solvent still shall not contain more than 60 kg of solvent per 100 kg of wet waste material.

(3) Filtration cartridges must be drained in the filter housing for at least 24 hours before being discarded. The drained cartridges should be dried in the dryer tumbler after draining if at all possible.

(4) Any other filtration or distillation system can be used if equivalency to these guidelines is demonstrated. For purposes of equivalency demonstration, any system reducing waste losses below 1 kg solvent per 100 kg clothes cleaned will be considered equivalent.

Sec. 3. Sections 2(c) and (d) are not applicable to plants where an adsorber cannot be accommodated because of inadequate space or to plants where no or insufficient steam capacity is available to desorb adsorbers. The District may exclude other plants from the scope of Sections 2(c) and (d) if it appears that other hardships justify such an exclusion.

2/ Enforcement of these provisions is dependent on the development of a satisfactory detector and of test methods.

Sec. 4. Compliance Procedures

(a) Liquid leakage shall be determined by visual inspection of the following sources:

(1) Hose connections, unions, couplings and valves;

(2) Machine door gasket and seating;

(3) Filter head gasket and seating;

(4) Pumps;

(5) Base tanks and storage containers;

(6) Water separators;

(7) Filter sludge recovery;

(8) Distillation unit;

(9) Divertor valves;

(10) Saturated lint from lint basket; and

(11) Cartridge filters.

(b) Vapor leakage shall be determined by _____.[3/]

(c) Dryer exhaust concentration shall be determined by _____.[4/]

(d) The amount of solvent in filter and distillation wastes shall be determined by utilizing the test method described by the American National Standards Institute in the paper, "Standard Method of Test for Dilution of Gasoline-Engine Crankcase Oils."

3/ See footnote 1, above.

4/ See footnote 2, above.

6.3 DISCUSSION

(Sec. 2.b) As noted, the EPA is now assessing the significance of vapor leaks in perc dry cleaning systems. If deemed significant, then an inexpensive monitor will be developed which can be used by operators and enforcement personnel to locate major vapor leaks. If deemed insignificant, Section 2.b can be deleted. The study of vapor leaks should be completed by May 1979.

(Sec. 2.d) Carbon adsorbers tested by the EPA have achieved much better control than 100 ppm outlet concentration. This figure was chosen because it is high enough to indicate "breakthrough" of the carbon bed. Breakthrough is a good indicator to enforcement officials of improper maintenance or operation of the adsorber.

(Sec. 2.e) Figures given for filter and distillation waste disposal are based on limited data and thus include margins of safety. A more stringent standard may be achievable. For purposes of equivalency, waste losses should be less than 1 kg of solvent per 100 kg of clothes cleaned.

(Sec. 3) Most coin-op cleaners are expected to fall under this exemption clause since space and steam capacity are not usually available. While some small commercial plants may fall under this exemption clause, most commercial and industrial perchloroethylene cleaners should be able to comply with Section 2 (c) and (d).

It is expected that because of the limited number of carbon adsorption equipment vendors, there may be problems in obtaining delivery of control equipment in the time frame outlined by State regulations. Regulatory agencies should be sensitive to this problem and provide extensions to compliance schedules where deemed necessary.

APPENDIX A. EMISSION SOURCE TEST DATA

EPA planned to test only as many plants as necessary to represent best available control in the dry cleaning industry. A number of parameters which affect emissions presented themselves for consideration. Dry cleaning plants differ in size, control techniques, design, capacity, types of clothes cleaned, climate of locality, soil composition, age of equipment, and maintenance history. The effect on emissions that some parameters have is small. EPA tested typical plants in two of the three industry sectors (commercial and industrial) as shown in Table A-1.

TABLE A-1. PLANTS TESTED BY EPA

(kg capacity of washers given in parentheses)

	Perchloroethylene
Coin-Op	None
Commercial	X (50,18)
Industrial	X (140)

A small and a large commercial perchloroethylene unit were tested. A description of these tests can be found in Sections A.1 and A.2. The difference between dry-to-dry and transfer units was explored in these tests.

A large industrial perchloroethylene unit was tested. The test is discussed in Section A.3. The unit was a relatively new design of transfer machine in which the washer and dryer nearly touch during transfer, thus reducing exposure time of the damp clothes to atmosphere.

No coin-operated perchloroethylene machines were tested. No adsorption systems in use on perc coin-ops in the United States were located.

All systems were tested by the methods discussed in Appendix B of this document.

All systems were tested by the methods discussed in Appendix B of this document.

A.1 PLANT A

Plant A's commercial operation, which uses perchloroethylene solvent in a 50 kg capacity machine, was tested by material balance (November 3-November 20, 1975). The machine is a Washex SM-11 and was installed in 1967. The system consists of a washer/extractor, muck cooker, two dryers, a regenerative filter and a Vic dual canister carbon adsorber. The carbon adsorber collects emissions from the washer door vent, the dryers, floor vents, and the distillation (muck cooker) unit. EPA not only performed a material balance of the unit, but also stack tested the carbon adsorber for perchloroethylene (by test methods also described in Appendix B).

The plant used two operations which are not normally used in dry cleaning services--fire-proofing and water repelling applications. The addition of these materials was accounted for in the material balance.

Table A-2 summarizes data from each test in the dry cleaning test program. It can be seen that emissions from this unit were about 4.1 kg of solvent per 100 kg of clothes cleaned. Outlet concentrations of perchloroethylene averaged about 25 ppm. This means that solvent consumption in the whole process was about 19 kg per day of which 1 kg was from the adsorber. Without an adsorber, total emissions would have more than doubled.

The adsorber was installed at least 15 years ago and the unit has had one major "overhaul" since that date (due to corrosion). It requires approximately 9 cubic meters or about 4 square meters of floor space. The original washer dryer system which the unit serviced was replaced in 1967.

This system demonstrated the performance of carbon adsorption as a control technique. The carbon in this carbon bed is over 15 years old and outlet concentrations are only 25 ppm when tested. The system suffered from inadequate housekeeping, however. Liquid leaks were sighted and buckets of perchloroethylene draining from water separators were left uncovered. The scent of perchloroethylene was prevalent. EPA feels that operation of this plant could have been improved by better housekeeping.

A.2 PLANT B

During the period April 7-20, 1976, a material balance was conducted on a small, commercial dry cleaning operation using perchloroethylene solvent (Plant B). A stack test of a carbon adsorber on the plant was conducted during one day of testing by Midwest Research Institute. The stack test involved integrated samples analyzed for total non-methane hydrocarbons.

Plant B consists of a dry-to-dry Vic Model 221 Strato System of 18 kg (40 pounds) capacity. During the course of the test, approximately 170 kg (370 pounds) of material were cleaned per day. Table A-2 summarizes the emission data taken from the material balance and stack test.

The system vents to a dual canister carbon adsorber from the dryer (during the entirety of the drying cycle), from floor vents, and from the washer door. Each carbon bed operates for one cycle of the washer/dryer and then is desorbed during the next cycle. There were some indications that the carbon beds were undersized. Limited data taken from a semi-continuous monitor indicate that breakthrough occurred on each bed during

its cycle. Average non-methane hydrocarbon concentration in the exhaust stream was 100 ppm.

A 14 cartridge (paper) filter was used to purify solvent in the systems. It was the only such purification device used in the system.

According to material balance and accounting for cartridge filter loss prorated to the course of this test, the dry cleaning system at Plant B had an emission factor of 2.1 kilograms of solvent used per 100 kilograms of clothes cleaned (based on machine capacity). Approximately 3.6 kilograms (7.9 pounds) of solvent were lost from the system per day. Of this 3.6 kilograms, the carbon adsorber lost 1.2 kilograms (2.6 pounds) at an average outlet concentration of 100 ppm. The cartridge filter accounted for an estimated 0.7 kilograms (1.5 pounds) loss per day.

The adsorber was built in as an integral part of the unit. It requires about 1.4 cubic meters of space or about 1 square meter of floor space.

A.3 PLANT C

Plant C is an industrial dry cleaning plant using perchloroethylene solvent. It is an American Laundry Machinery system which includes washer/extractor, a "kissing" dryer, distillation unit, chemical separator, oil cooker and single bed carbon adsorber. The adsorber collects emissions from the washer and dryer. The capacity of the washer is about 140 kg per load but shirts are loaded at about 90 kg per load because of the number of articles per kilogram. Pants are loaded at capacity.

The "kissing" washer/dryer is a relatively new innovation in the industry. At the conclusion of washing, the dryer is pneumatically rolled to within 0.3 meters of the washer, both doors are opened and the clothes are transferred by tumbling. This design greatly reduces the time that solvent laden clothes are exposed to the atmosphere.

EPA performed a material balance on the system and also tested the carbon adsorber. Results of the test are shown along with other tests in Table A-2. The table shows that solvent usage was a very low 2.5 kg of solvent per 100 kg of clothes cleaned. The entire system lost about 40 kilograms of solvent per day of which about 0.1 kilograms were emitted from the adsorber. Most of the losses were accounted for in a special washer loading exhaust and in a distillation unit vent. Both were vented to atmosphere and emitted approximately 24 kilograms of solvent per day. System changes were being initiated to vent these two sources to the adsorber. The outlet to the carbon adsorber averaged around 3 ppm.

Both the material balance and the adsorber test demonstrated the efficiency of this system. Exemplary housekeeping practices were followed at the plant and attention was paid to methods of improving performance. The equipment was installed from 1970 (washer, distillation unit, and oil cooker) to 1975 (kissing dryer in early 1974 and the carbon adsorber in May, 1975). No solvent leaks were detected by sight or smell.

The adsorber required about 20 cubic meters of space and about 6 square meters of floor space. It was retrofitted in 1975.

TABLE A-2. DRY CLEANING TEST DATA [1,2,3,4,5,6]

Plant	System	Clothes Throughput	Total System Emissions kg/100 kg*	Carbon Adsorber Outlet kg/100 kg	Muck Cooker Filter, or Still kg/100 kg	Water Separator	Carbon Adsorber Inlet kg/100 kg
A	Perchloroethylene transfer	455 kg/day	4.1	0.2	0.73	0.07	4.6
B	Perchloroethylene dry-to-dry	170 kg/day	2.1	0.7	0.4	0.001	23
C	Perchloroethylene transfer	1750 kg/day	2.5	0.0002 washer loading = 1	0.026 still vent = .35	0.026	8.1

*Based on capacity of machines.

A.4 REFERENCES

1. Kleeberg, C.F., "Testing of Commercial Perchloroethylene Dry Cleaner," test report on Hershey, Pennsylvania test to James F. Durham, EPA, May 14, 1976.

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4. Scott Environmental Technology, Inc., "Air Pollution Emission Test - Hershey Dry Cleaners and Laundry, Hershey, Pennsylvania," Report No.76-Dry-1 to EPA, March, 1976.

5. Midwest Research Institute, "Test of Industry Dry Cleaning Operations at Texas Industrial Services, San Antonio, Texas," Report No.76-Dry-2 for EPA, April, 1976.

6. Midwest Research Institute, "Air Pollution Emission Test, Westwood Cleaners, Kalamazoo, Michigam," Report No.76-Dry-3, for EPA, June, 1976.

APPENDIX B

COMPLIANCE TEST METHODS AND LEAK DETECTION EQUIPMENT FOR PERCHLOROETHYLENE DRY CLEANERS

B.1 COMPLIANCE TEST METHODS

An emission measurement can be made by several methods, all of which were analyzed as possible compliance test methods before choosing the equipment performance criteria discussed in Chapter 6.0.

a) Material balance

b) VOC concentration limit on dryer exhausts

c) Total mass limit for all emission points

d) Equipment performance specification

While the material balance was determined to be the best method of truly measuring solvent losses, equipment performance specifications are preferred for enforcement of a standard. Still, the material balance test method was used to develop background data for this document and is therefore discussed. The method has the following advantages:

a) Total system emissions can be checked. This is not the case for a dryer exhaust limit where only one emission point would be monitored.

b) A material balance is more direct and simple than the test equipment and procedures associated with a stack test.

c) Many existing plants keep records of clothes and solvent throughput. These records could be used to assist and check the material balance.

d) The material balance method, which determines emissions on a mass per mass basis, does not distinguish between large and small plants as a mass per day limit does. This means that best control technology is applied across the board to all plants.

The primary disadvantage of the material balance is that it is very time consuming. While the material balance is optimum for determining exact emissions it is suggested that other methods, specifically equipment performance requirements, should be used for enforcement.

The following sections of this chapter detail the material balance, stack test, and solvent sampling techniques. In addition, leak detection devices are discussed in Section B.2 in terms of availability and cost.

B.1.1 Material Balance Methods

A material balance requires measurement of clothes and solvent over a number of loads in addition to solvent levels in the system before and after testing. All significant sources of solvent must be accounted for. The following method was developed by EPA with the assistance of an EPA contractor and the International Fabricare Institute. The method outlined here should be considered flexible for the different processes in the industry.

A. Before the test begins, solvent in the system should be accounted for by the following methods:

1. Drain entire filter contents (powder, soil, and solvent) to muck cooker or to holding tank (if cooker is not used).

2. Begin distillation/cooking or other treatment of muck. Dry cartridge filters, if applicable.

3. Begin desorbing vapor absorber.

4. On completion of cooking or drying, remove and discard dry residue. Replace cartridge filters with new filters.

5. Dry out adsorber bed. Put desorbed solvent into cleaning machine base tank.

6. Start up wash pump to fill filter housing (ideally, machine should be on continuous recirculation--solvent circulating between base tank and filter and returning).

7. Add any detergent needed. (Take solvent sample, if needed--see below for description of analysis methods.)

8. Measure solvent level by dip stick or gauge in base tank. (Account for residue volume in bottom of tank.)

9. Put in filter and carbon. (Samples and total weights of this material can be taken upon each removal from the cooker to determine losses associated with the filter system.)

B. During the test:

Record weight of all loads.

C. After the test period, recreate conditions of first solvent measurement by repeating Steps A.1 through A.7. Another sample is taken to determine detergent concentration in the "charged" solvent, if needed (see below).

The solvent loss in cartridge filters is a fixed loss for the number of loads recommended for use. In other words, if a filter vendor recommends 200 loads of solvent as the filter life, the loss from filter change is the same as the 200 load whether there are 50 loads or 300 loads. The loss from filters for a test of less than the recommended filter life should be prorated to the life of the filter. A loss of 1 kilogram after 50 loads on a filter of

200 load life should be considered in the calculation as a loss of 0.25 kilograms.

Fixed losses are a significant factor in small machines. A 5 kilogram load in a 12 kilogram capacity machine will have nearly the same loss as a 12 kilogram load in the same machine. In calculating kilograms of clothes throughput in machines, the vendor capacity times the number of loads should be used instead of the actual load. The IFI and other organizations can relate cubic feet of washer volume to capacity by available factors too extensive to list here.

To determine solvent consumption, the solvent level (minus detergent, sizing, etc.) of the initial measurement (Step A.8) is compared to the solvent level (minus detergent, sizing, etc.) of the final measurement (Step C.2). All solvent added during the test period should be accounted for.

To determine the system emission factor for the test period (which should be for at least one work week), the solvent consumption is divided by the clothes throughout the system. Since the test site need only be prepared by an enforcement official and not attended, total manhours required per test is less than 10.

The following discusses sample analyses for solvent taken from the system. A 0.5 liter sample is sufficient for analysis.

According to the IFI, samples should be analyzed for detergent concentration, moisture, non-volatiles, dry sizing, and insoluble materials. A Hyamine 1622 or Aerosol OT Titration should be used for detergent concentration reported on a volume/volume percent basis. The moisture content is determined by a Karl-Fischer titration procedure and reported as grains of water/100 millilitres of solution. Non-volatile residue is determined gravimetrically by a steam bath evaporation of a measured volume of solvent and weighing the residue. Dry sizing content is determined by extracting the non-volatile residue with boiling ethyl alcohol. Insoluble material content is to be determined gravimetrically after filtration of a volume of solvent through a 0.20 micrometer membrane.

For determining the amount of solvent in filter materials (muck and distillation waste) the test method described by the American National Standards Institute in the paper "Standard Method of Test for Dilution of Gasoline-Engine Crankcase Oils," should be used. To be derived are the kilograms of VOC per kilogram of discarded filter muck. This method can be used for the enforcement of the performance requirements of RACT.

EPA found that results were consistently 8-10 percent different when these accounts for material other than solvent were not made. It is felt that after determining total system solvent volume consumed during the course of the test 9 percent can be subtracted out as other materials. The remaining 91 percent can be considered pure solvent emitted to the atmosphere. The test methods are described here for reference only.

B.1.2 Emission Measurement Method for Perchloroethylene From Adsorber Vent

The primary method used to gather emission data has been the integrated bag sampling procedure followed by gas chromatographic/flame ionization detector analysis. Appendix B, Draft EPA Method 23: "Determination of Total Halogenated Organics from Stationary Sources," describes this approach. For this method, the integrated bag sampling technique was chosen over charcoal adsorption tubes for two reasons: (1) less uncertainty about sample recovery efficiency, and (2) only one sample portion to analyze per sample run. A column identified by a major manufacturer of chromatographic equipment as useful for the separation of chlorinated solvents is employed.

The method was written after an initial EPA funded study of halogenated hydrocarbon testing revealed areas where improvements in the bag sampling technique were needed. In particular, leaking bags and bag containers were cited as a probable cause of poor correlation between integrated and grab samples taken at an emission site by that contractor. In light of these findings, more rigorous leak check procedures were incorporated. The first test conducted by EPA with the improved method to gather emission data utilized both integrated bag and grab sampling techniques as a form of quality control. For the three days during which tests were made, very good correlation between the two techniques was obtained. Subsequent to these tests, a final draft of this method was prepared that incorporates further leak checks as an additional precaution against erroneous data. These additions were suggested by an EPA contractor that was studying the vinyl chloride test method. This contractor coincidentally performed the second and third dry cleaning emission data tests, and was previously aware of the need for exercising particular caution with respect to leak detection.

The costs for conducting a Method 23 emission test in triplicate will depend on the length of the cleaning cycle and are accordingly estimated at $5000 to $10,000 per unit. A simplified version of this test may run as low as $200. The testing costs per unit would be lower if several units at a single site were serially tested. The high cost of this test precludes its use on a day-to-day enforcement of RACT. It is expected that compliance with the 100 ppm RACT definition will be demonstrated with inexpensive portable analyzers.

B.2 Leak Detection Methods

There are several types of portable, self-contained instruments currently available for leak monitoring in dry cleaning facilities. The principles of operation are catalytic-oxidation, flame ionization, and infrared energy absorption. All three types of detection will respond to practically all types of organic materials although the relative responses to the different types will vary.

For halogenated solvent operations where a single compound is predominant, the instruments can be calibrated with that compound and the results will be on that basis. Examples of some manufacturer's reported ranges for perchloroethylene are: (1) catalytic-oxidation, 27-13,000 ppmv; (2) flame ionization, 2-20,000 ppmv; and (3) infrared, 0.5-200 ppm +, depending on configuration.

The cost of a monitoring instrument ranges from about $900 to $4000, depending on the detection principle, operating features, and required accessories associated with the different instrument types and vendors.

EPA has contracted to examine several of these alternatives, including less expensive systems than discussed above, the object of the study being to develop an easy to use, inexpensive monitor for vapor leak detection.

B.3 SUMMARY

This chapter has detailed the methods used to develop background information for this study. For the most part these methods are too expensive and cumbersome to be used as effective enforcement tools. It is suggested that portable detectors, to be analyzed and developed by EPA in the near future, be used to determine the extent of vapor leaks in a system and also be used to determine compliance with dryer control requirements. Solvent in filter and distillation system wastes can be determined by methods discussed in this chapter.